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Rareness of certain Mediterranean ant species: fact or artifact?

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Summary

A checklist of the ants recorded during five years in a small urban area (400 m^2) in Sant Cugat (Barcelona, Spain) is presented. 23 species nest in the area, 7 species (hypogaeic or parasitic) probably nest and 5 species nest in the vicinity; five additional species have also been recovered from the area. The rarity of some of these (*Leptanilla* sp., *Hypoponera abeillei* (Emery), *Cryptopone ochraceum* (Mayr), *Smithistruma tenuipilis* (Emery), *Epitritus argiolus* Emery, *Trichoscapa membranifera* Emery, *Chalepoxenus muellerianus* (Finzi), *Anergates atratulus* (Schenck), *Plagiolepis xene* (Schenck), *Lasius carniolicus* Mayr) and the high number of species suggest that a) rarity in Mediterranean ant species may be explained by the insufficient sampling in time of adequate microhabitats (hypogaeic species) or by the inconspicuousness of social parasitic species, and b) that previously published species lists of ants from Mediterranean habitats might be rather incomplete.

Introduction

Several aspects converge in the rare species issue: purely scientific interests, simple curiosity or the pleasure in looking for – and finding – unusual specimens, phenomena or infrequent situations (Eisner, 1982; Wilson, 1984a; Kruckeberg and Rabinowitz, 1985). Anyone who has gone through the experience of finding one of the so called "rare species" knows of the excitement and pleasant, complex emotions it evokes.

Rarity, in its several meanings, has been dealt with by many authors (Preston, 1948; Drury, 1974; Harper, 1981). The main biological properties usually associated with rareness are a) small population size, b) geographically restricted, localized populations and c) habitat specificity. Non-biological criteria are sometimes used, viz. absence of collection for several decades, discovery outside the normal geographical range, or excessive difficulty in finding it by an expert in a single season (Rabinowitz, 1981).

It is often the case that the number of "rare species" at a particular site increases beyond a point such that one may wonder whether they are actually rare. Are they "rare" because of their small population size? Or are they "rare" because of the use of inadequate techniques to find them? Although methods to document completeness have been devised (Miller and Wiegert, 1989), a definitive judgement depends on the degree of field experience and search intensity. However, assuming an author has a proper knowledge and that his/her observations agree with published facts, it seems reasonable to admit rarity as a characteristic inherent in some species.

Here, we will suggest the inaccuracy of various generalized opinions on an insect group: ants. We present a simple inventory from a single locality; the quality of both the list and the site are pertinent to the rare species problem, at least for the Mediterranean area. There follows, as a corollary, a re-evaluation of the degree of completeness of the published lists of ants in Mediterranean habitats.

A second aim of this work is on the topic of species diversity. As the textbooks state, there is an increase in species diversity with increased structural complexity of the ecosystem. This has been documented for some ecological groups such as plankton, or taxonomical groups such as birds (Margalef, 1977). Ants are an adequate group to test for generalizations on species diversity. In particular, more complex vegetation should lead to a higher diversity of microhabitats and, therefore should contain a higher number of ant species. In addition to habitat diversity, other factors may influence the number of species in a given area (altitude, substrate heterogeneity, past disturbances), but they have not been addressed in this study, because the data set used refers to a regional (Mediterranean) scale, and at this level, habitat diversity is the only factor precisely defined by all authors. We conclude that the published data do not conform with theoretical expectations because of inadequate sampling methods and techniques. We suggest a more rigorous approach to sampling programmes.

Locality and methods

This study was conducted in a garden (800 m^2; studied only 400 m^2) within the urban area of Sant Cugat des Vallès (Barcelona), at 41° 30′ N, and an altitude of approx. 200 m, with a building 25 years old covering an area of 100 m^2. The 400 m^2 studied included 200 m^2 of cemented tracks, 100 m^2 of lawn irrigated twice a week in summer and with some scattered fruit trees on a field worked 1–2 times a year, free of insecticides. A garden contiguous to our study site was poorly attended with three weeping willows (*Salix* sp.), two black poplars (*Populus* sp.), one walnut, 21 conifers, some fruit trees and several bushes. Mean annual temperature is 14.5 °C, and mean annual precipitation is 563.6 mm (mean for ten years).

Our survey was intended to be an unrestricted representation of the ant fauna, and this was to be attained with an actual and conscious bias in the search.

Most sexuals were collected alive or dead in a small blue pond (2 × 1.5 m), and some individuals were recovered adhering by their wings on the dew over

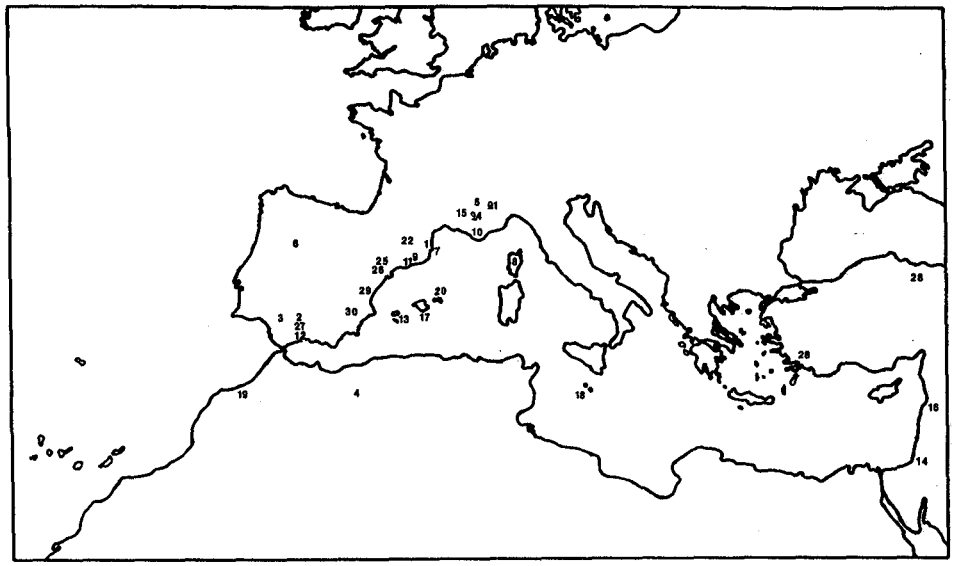

Figure 1. Geographical localization of sampling sites of species lists (numbers as in Tab. 1). Sant Cugat is located 5 km from number 9

diverse surfaces (metallic door, car, etc.). The pond was set for a month in 1986, two and a half months in 1987, three months in 1988 and two months in 1989; it was exposed during the day (usually covered at night) and it was inspected every 4–5 days, always in the afternoon. In addition, a classical entomological survey of ants under stones, in the soil, on trees, etc. was carried out on each sampling occasion. The entire study period extended over five years, from 1985 to 1989.

As far as species diversity is concerned, comparisons were limited to Mediterranean checklists, from 32° N to 46° N (Fig. 1). The 31 studies in Tab. 1 provided estimates of the checklists for each area. We used linear regression analysis to explore the dependence of the checklist (local species diversity, NESP) on the structural complexity of the area, estimated by the full number of habitats (as reported by authors, NHAB) included in each area. In addition, the relevance of the sampling effort devoted to exploring each study area was examined by looking at the relationship between the number of sites sampled (NSS) and the number of habitats (NHAB) as reported by authors. We calculated all regressions with the untransformed data, and also tried several transformations, inspected normal probability plots of residuals and payed attention to outliers. In all cases the log transformation was finally the most satisfactory. In a second step, we explored the potential effect of sampling effort in determining the number of species (NESP), i.e. the efficiency in finding a given number of species. Whenever possible, habitats reported by authors in each reference in Tab. 1 were grouped in ten types of habitats (Tab. 2). Thus, NSS within each habitat type in each study of Tab. 1 was used as an estimate of the sampling effort devoted to that particular replicate of each habitat type. There were 85 samples taken in all 10

Table 1. Range of ant species diversity (N) in various sites per habitat from several Mediterranean areas. NESP: total number of species; NSS: total number of sites sampled. NHAB: Number of habitats investigated by authors (oakwood, evergreen oak wodd, pine wood, mixed forests, scrubland, pastures, ruderal, etc.). *: Studies from which some sites were chosen for Tab. 2. Surface could not be used since this is seldom reported accurately

Zone	N	NESP	NSS	NHAB	Author
1. Alberes (F)*	4–23	50	25	7	Sommer (1984)
2. Alfacar, Sa. (E)*	3–22	62	32	15	Pascual (1986)
3. Andalucía (E)*	11–25	65	14	7	De Haro & Collingwood (1977)
4. Algeria (DZ)	8–32	121	166	24	Cagniant (1973)
5. Bas-Languedoc (F)*	2–29	57	59	13	Bonaric (1971)
6. Batuecas (E)*	6–13	25	6	5	De Haro (1974)
7. Cabo de Creus (E)*	6–10	19	5	4	De Haro (1982)
8. Corsica (F)*	9–20	67	12	12	Casevitz (1974)
9. Collserola, Sa. (E)*	10–21	27	15	3	Lombarte (1986)
10. Crau (F)*	10–11	14	4	1	Bigot et al. (1983)
11. Garraf (E)*	11–20	34	19	5	Restrepo et al. (1985)
12. Granada (litoral) (E)	1–19	47	70	7	Ortiz (1985)
13. Ibiza, Formentera (E)*	6–15	28	17	6	De Haro et al. (1986)
14. Israel (IL)	5–15	49	14	13	Ofer et al. (1978)
15. Languedoc (F)*	2–10	21	24	4	Passera (1977)
16. Lebanon (RL)	2–13	100	182	20	Tohmé (1969)
17. Mallorca, Cabrera (E)*	11–22	44	98	14	Comín (1988)
18. Malta (M)*	10–20	28	23	5	Baroni Urbani (1968)
19. Mamora (MA)	7–15	32	19	5	Bernard (1969)
20. Menorca (E)*	10–23	30	21	7	Comín (1977)
21. Mt. Ventoux (F)*	1–24	55	58	17	Du Merle (1978)
22. Catalan Pyrenees (E)	1–10	55	89	15	Espadaler (1979b)
23. Port-Cros (F)	3– 8	24	21	5	Bernard (1977)
24. Quercy (F)*	5–14	20	4	1	Passera (1968)
25. Sa. de Prades (E)*	7–20	39	11	11	Alonso & Espadaler (1981)
26. Sa. de Prades, etc. (E)*	9–27	52	13	6	De Haro & Collingwood (1981)
27. Sierra Nevada (E)*	1–19	74	54	9	Tinaut (1981)
28. Turkey (TR)	3–14	61	26	12	Aktaç (1976)
29. Valencia (E)*	12–16	21	3	3	Pardo et al. (1985)
30. Sa. Aitana-Alfaro (E)*	9–18	40	12	4	De Haro & Collingwood (1988)
31. Sant Cugat (E)	40	40	1	1	this study

Table 2. Habitats investigated, number of sites (S) sampled of each habitat across all studies, mean number of ant species (M), standard deviation and coefficient of variation. For details concerning floristic composition and physiognomy of these habitats see Braun-Blanquet (1979), Bolós & Bolós (1950), Folch (1981)

Habitat	S	M	S.D.	C.V.
1. Evergreen oak forest	10	22.6	12.5	55.66
2. Mountain oak forest	6	23.0	11.5	50.10
3. Macchia	10	18.2	5.3	29.62
4. Silicic scrublands	7	21.4	9.5	44.58
5. Calcareous scrublands	10	17.6	8.3	47.32
6. Tomillares	4	12.5	6.5	52.45
7. Spiny cushion-like scrub	2	13.5	9.1	68.08
8. Dunes + halophilous veg.	9	18.2	10.6	58.70
9. Ruderal	11	16.9	7.4	43.97
10. Pine forests	16	20.2	10.7	52.98

habitat types. We investigated whether differences in species diversity existed between the ten habitat types, using a covariance analysis, in which NSS represented the covariate. The analysis was performed on the square root of NESP, using the MGLH procedure of Systat (Wilkinson, 1986).

Results and discussion

Species quality

Forty ant species grouped in 23 genera were collected during five years (1985–1989) (Tab. 3, Fig. 2). Apparently, this is an exceptional number for a Mediterranean locality with the above-mentioned characteristics. Twenty-three species were nesting; seven more were most probably nesting (hypogaeic or parasitic), judging by the high number of sexuals collected. Among the remaining ten species, five were found in the vicinity (5–20 m away). Nothing can be commented about the other five species.

Several species (see *, Tab. 3) are considered by myrmecologists, the authors included, as interesting and rare species; they are all unusual in published faunistic accounts, but probably present in many biotopes. Only two males and a few workers from the genus *Leptanilla* Emery are known from the Iberian peninsula (Baroni Urbani, 1977; Espadaler, 1987; Tinaut, 1987; Martínez, 1990). Less than ten localities are known for *T. membranifera* (Emery), *S. tenuipilis* (Emery), *E. argiolus* Emery altogether (Medina, 1982; Espadaler, 1979a; Espadaler and Riasol, 1983; Tinaut, 1988). *C. ochraceum* (Mayr), *C. muellerianus* (Finzi), *A. atratulus* (Schenck), *P. xene* (Schenck) and *L. carniolicus* Mayr are somewhat more abundant, but always unexpected.

Very little is known of the life-cycles, state of populations, or reproductive biology, in short, the natural history of all these species but *Chalepoxenus* (Buschinger et al., 1988). Abundance of local populations of the "rare" species might be limited by biotic agents such as predators and pathogens, but our intuitive guess is that they would not account for the rarity of these species. In fulfilment of the criteria given by Rabinowitz (1981) we note that rareness in the above-mentioned species seems free from such constraints as the myrmecologist's experience or geographical scale. In effect, they have been found by different authors at distinct moments of their careers, and known localities are distributed all around the Mediterranean Basin, are widely separated and seldomly reported (Baroni Urbani, 1971; Bernard, 1968). The contour of the Mediterranean sea (the Eumediterranean zone of plant geographers) is probably the most studied region of the world – not the best known: C. Emery, B. Finzi, A. Forel, C. Menozzi, F. Santschi from the end of the 19th century, and C. Baroni Urbani, F. Bernard, C. Collingwood among many others nowadays have provided an enormous amount of faunistical data. Egypt and Libya are poorly known, but the scarce information confers a distinctive image from other Mediterranean countries. Rare ants are not easily collected in standard surveys. We suggest that the suposed rarity of many Mediterranean ants may be better

Table 3. Ant species found in an urban garden at Sant Cugat (Barcelona, Spain). See characteristics in text. *: species usually considered as rare and interesting; P: social parasite; H: hypogaeic; T: Tramp species; D: dulotic; NC: Confirmed nesting species; NP: Probably nesting; > 100: swarming, in large numbers. Sexuals usually collected in the small pond

Species	Sexuals	Specimens Fem.	Specimens Males	NC	NP
Cryptopone ochraceum (*, H)	X-88; IX-89	4			
Hypoponera abeillei (*, H)	VIII-87; VIII-88-89	1	5		+
Hypoponera eduardi (H)	X-85; IX-86; IX-87; IX-X-88; IX-89	11	17	+	
Hypoponera punctatissima (H)	VII-VIII-88	2			
Ponera coarctata (H)	VIII-85; VIII-IX-87-88-89	3	54	+	
Leptanilla sp. (*, H)	IX-86; VIII-IX-87; VII-IX-88-89		298		+
Anergates atratulus (*, P)	VII-85	1			+
Aphaenogaster senilis	IX-86; VI-IX-87; VIII-IX-88-89	> 100		+	
Aphaenogaster subterranea	VIII-X-88; VIII-IX-89	4		+	
Chalepoxenus muellerianus (*, D)	III-87		1		
Crematogaster scutellaris	IX-X-88; IX-89	> 100		+	
Epitritus argiolus (*, H)	VIII-IX-86; VIII-X-87; VIII-IX-88-89	5	94		+
Leptothorax lichtensteini	VIII-IX-87-88; VIII-89	> 100		+	
Leptothorax niger	VII-88	1			
Leptothorax rabaudi	VII-89	1	1	+	
Leptothorax recedens	VI-85; VII-87; VII-VII-88	> 100		+	
Messor barbarus	IX-88	3	6	+	
Messor structor				+	
Myrmecina graminicola (H)	VII-86; VII-IX-87; VIII-IX-88; IX-89	17	39	+	
Myrmica scabrinodis	X-85; IX-87	> 100			
Pheidole pallidula	VI-86; VI-VII-87; VII-IX-88; VIII-89	> 100		+	
Smithistruma tenuipilis (*, H)	VIII-IX-87; VIII-88; IX-89	1	5		+
Solenopsis fugax	X-85; IX-86; VIII-X-88-89	> 100		+	
Solenopsis sp.	X-88-89	> 100			+
Tetramorium impurum cfr.	VI-85-86-87-88-89	> 100		+	
Tetramorium semilaeve	VI-87; VII-88; VI-89	> 100		+	
Trichoscapa membranifera (*, H, T)	VIII-86; VIII-IX-88-89	11	9	+	
Tapinoma nigerrimum	VI-88		2		
Camponotus aethiops	VI-87; VI-88-89	> 100		+	
Camponotus cruentatus	VII-88		3		
Camponotus fallax				+	
Camponotus truncatus				+	
Formica rufibarbis	VI-87; VII-89			+	
Lasius alienus	VIII-89		2		
Lasius carniolicus (*, P)	X-88	1			
Lasius mixtus (P)	IX-87	1			
Lasius myops (H)	IX-85; X-86; IX-X-88; IX-89	> 100		+	
Lasius niger	VI-86; VI-87; VII-88	> 100		+	
Plagiolepis pygmaea	VI-VII-87; VII-VIII-88; VII-89	> 100		+	
Plagiolepis xene (*, P)	IX-86; VII-VIII-87; IX-88; VIII-89	12			+

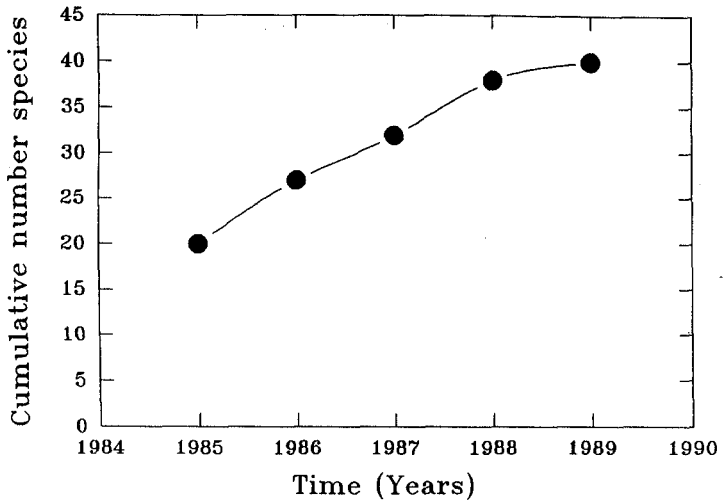

Figure 2. Cumulative number of ant species sampled during a five year study in an urban garden at Sant Cugat (Barcelona) (see characteristics in text)

explained by their inconspicuity – small social parasites that are naturally rarer than their hosts – or by the scarcity and sampling difficulty of suitable micro-habitats in the case of hypogaeic species.

The entomologist, in his routine work of inventory, may be seen to act as a generalist predator, finding a broad spectrum of prey, that is, typically the common species. Alternatively, he/she may be seen to use another strategy, i.e. to sit and wait, typical of many specialists, which requires long periods of waiting. For the entomologist, the last strategy is the most effective, as demonstrated by both the data presented here, and the extreme abundance of social parasitic or slavery ants (usually considered rare) found in Switzerland and, by extension, in Western Europe (Wilson, 1984b; Passera, 1984) compared with all other areas studied. Even though it is a small country, Switzerland has produced good myrmecologists such as A. Forel (1848–1931) and H. Kutter (1897–1990), who simply knew what to look for and where, and did it for long time, with the result that many rare species were found.

In spite of the different circumstances (30° 30′ S latitude, Australia) it is interesting to mention that Majer and Brown (1986) find public gardens to be a refuge of native ant species, and relate area and age with specific richness.

Species richness

The calculated regressions from data of Tab. 1 (i.e. Sant Cugat not included) are presented in Tab. 4. The total sampling effort, estimated by the number of sites, increased significantly with the number of habitats sampled (Eq. 1, Fig. 3). Species diversity also increased significantly with the number of habitats (Eq. 2, Fig. 4). The slope of 1.114, in Fig. 3, indicates that sampling effort was effec-

Table 4. Relationship between the number of sites sampled (NSS) in each study of Tab. 1 (Eq. 1), or the number of species (NESP) found (Eq. 2), and the number of habitats (NHAB)

	R^2	Standard error of estimate	Significance of slope (P value)
1. Log NSS = 1.114 log NHAB + 0.42	0.636	0.28	< 0.001
2. Log NESP = 0.57 log NHAB + 1.13	0.708	0.12	< 0.001

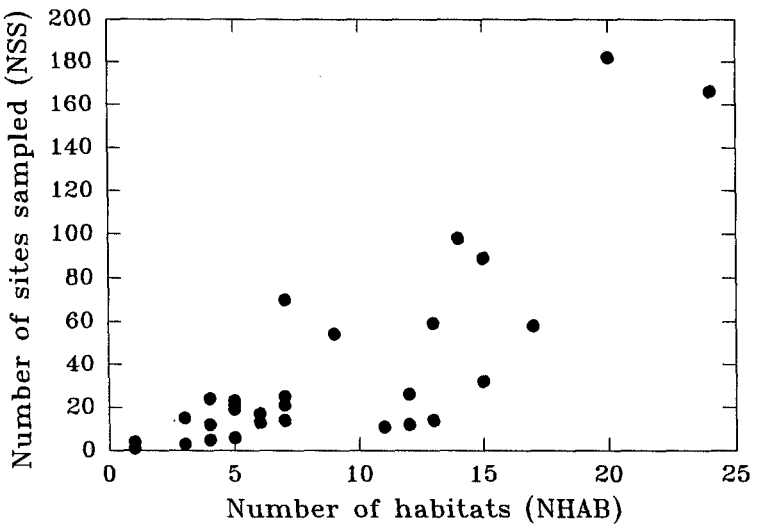

Figure 3. Relationship between the number of sites sampled (NSS) and the number of habitats (NHAB) in Mediterranean ant communities (untransformed data, Tab. 1)

tively, though slightly, increased per unit of increase in the number of habitats. This implies that different areas are searched with different sampling intensities, and in addition it reflects the knowledge shared by many myrmecologists that intrinsic differences in species diversity between areas do occur, i.e. areas with more complex vegetation types should show a higher species diversity – probably because they contain a higher microhabitat diversity – and therefore more sampling effort should be given to them. This is well-known to anyone working with groups as diverse as birds, butterflies or beetles (see Margalef, 1991), and is noticeably expressed in Fig. 4. However, it is important to ask how important sampling effort is in determining the species diversity of a given locality. Analysis of covariance of data in Tab. 1 do not support the naturalist's view (Tab. 5), since when the ten types of vegetation are compared at a given sampling effort, species diversity differences among them were not statistically significant ($F = 1.41$; $P = 0.1989$). Two explanations are possible for the contrast between the statistician's and the naturalist's point of view. First, areas with more complex vegetation are in fact not sufficiently explored (the slope in Fig. 4 should be higher, i.e.

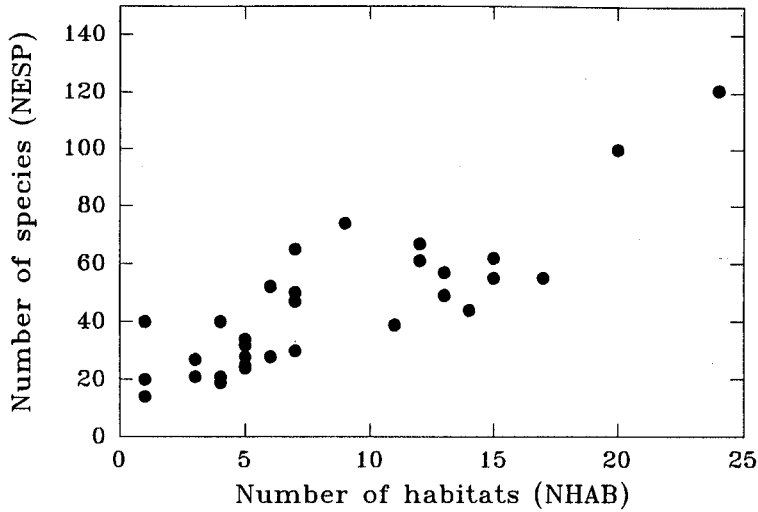

Figure 4. Relationship between the number of species (NESP) and the number of habitats (NHAB) in Mediterranean ant communities (untransformed data, Tab. 1)

Table 5. Differences in species diversity among the 10 habitats shown in Tab. 2, as studied by a covariance model, with the number of sites sampled (sampling effort) as covariate. The dependent variable used was the square root of the number of species. Data included in this table belong to those of Tab. 1 (*) that could be unequivocally assigned to one of the habitats considered in Tab. 2

A. Analysis of variance

Source	df	Sum of squares	Mean Square	F-value	P-value
Habitat	8	6.755	0.844	0.940	0.4898
NSS	1	20.562	20.562	22.90	0.0001
Habitat * NSS	8	5.804	0.726	0.808	0.5979
Residual	66	59.261	0.898		

B. Adjusted ANOVA

Source	df	Sum of squares	Mean Square	F-value	P-value
Habitat	9	11.167	1.241	1.411	0.1989
NSS	1	26.587	26.587	30.238	0.0001
Residual	74	65.065	0.879		

sampling effort should increase in a nonlinear mode). Second, a potential impoverishment of species diversity does occur in areas with more complex vegetation, as compared with simpler ones. Evidence to discriminate between the two explanations should be obtained with a distinct data set. Our own data from Sant Cugat may be used as an external source of data, which is strongly persuasive in favour of the first interpretation above. When Eq. 2 (Tab. 4) is recalculated to include Sant Cugat, the only outlier appearing is precisely Sant Cugat (standard-

ized residual = 3.45). The high species number of found in Sant Cugat implies that, given an adequate sampling effort, species diversity should increase with habitat diversity, and therefore, results given by the ANCOVA are actually a reflection of incomplete sampling undertaken in studies of Tab. 1. Most surveys in Tab. 1 were carried out with no evaluation of their degree of completeness. Wiens (1981) has shown how diverse community patterns of shrubland birds may be if derived from single-sample surveys. Presumably the same applies to ant communities, where single sample surveys are the most common procedure. We suspect that if similar conclusions were obtained from other taxa, it would reinforce the knowledge that knowing how many species there are in a given area may be an interesting and challenging work (Lawton, 1990).

Checklists

Two hundred and fifteen species belonging to 44 genera are known from the Iberian peninsula (Collingwood, 1978, updated and unpublished data). In other latitudes the numbers are very different: the British Isles have 41 native species (Bolton and Collingwood, 1975), but a single tree from the Peruvian rain forest (Wilson, 1987) may harbour 43 species. This contrast is just a reflection of the broad latitudinal variation of gamma diversity well known in ants (Kusnezov, 1957; Lévieux, 1983), and in many other terrestrial groups (Fisher, 1960; Begon, Harper and Townsend, 1986).

The faunistic image we obtained after five years of study is very different from that of general faunistic surveys or checklists, which usually give a number of 10–20 species per biotope: intensive samplings, and extended in time, of an urban locality provided in a five year period an unsuspected and highly diverse myrmecological faunistical image. This cannot be interpreted as an area effect. The well known species-area relationship is usually explained as a result of habitat diversity, or as an effect of the area *per se* (Williams, 1964; MacArthur and Wilson, 1964) but, alternatively, as a sampling artifact (sampling hypothesis, Connor and McCoy, 1979). In our case (Sant Cugat) we can reject area as an explanation of species diversity, because of its small size. We do not think that spatial heterogeneity, in our case, could be the source of the high number of species, even though it is difficult to measure. Thus, a slightly degraded evergreen oak forest, or the majority of Mediterranean mixed forests, which are extremely complex in physical structure, have a larger number of available microhabitats than our study area, and, therefore should be richer in species. Hence, we suggest that published inventories or species lists of Mediterranean ants can be highly biased (towards easily detected species), and they should be seen as a tentative list of the entire ant community. Even if admitting a microhabitat mosaic in our locality we cannot but think of higher species numbers for the localities quoted in Tab. 1. We must add that the present ant list (Sant Cugat, Tab. 3) is probably incomplete, since the samples universe is partial in time. Preston (1948) concluded that the number of moth species collected during 4 years at a North American locality was 80% of the expected total. His estimates were based on 56131 individuals. Many other examples are quoted in Williams (1964).

Concluding remarks

Collectors should evaluate the sampling effort required before any survey (Heck et al., 1975) by methods such as estimates of cumulative diversity curves, diversity spectra or rarefaction techniques. This would also be pertinent in studies of environmental protection and/or impact analysis (Miller and Wiegert, 1989). Intense sampling efforts in space and with appropriate techniques should provide more complete faunistic lists. This last conclusion, postulated and defended by Williams (1964), seems to be obvious, but is usually neglected.

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